W. D. Andrews

PRELIMINARY INSTRUCTIONS

FOR

FREQUENCY METER SETS SCR-211-P and SCR-211-T

(REVISED EDITION)

Manufactured By

ZENITH RADIO CORPORATION

RESTRICTED

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SAFETY NOTICE

WHEN BATTERIES ARE BEING LOADED INTO THE BATTERY COMPARTMENT, DO NOT TOUCH THE CONNECTING TERMINALS AS SEVERE SHOCK WILL RESULT.

WARNING:—In using this meter to calibrate a transmitter, there should never be any direct connection between the meter and the transmitter.

DESTRUCTION OF ABANDONED MATERIAL IN THE COMBAT ZONE

In case it should become necessary to prevent the capture of this equipment, and when ordered to do so,

DESTROY IT SO THAT NO PART OF IT CAN BE SALVAGED, RECOGNIZED, OR USED BY THE ENEMY, BURN ALL PAPERS AND BOOKS.

means:—

1. **Explosives, when provided.**
2. **Hammers, axes, sledges, or whatever heavy objects are readily available.**
3. **Burning by means of incendiaries such as gasoline, oil, paper, or wood.**
4. **Grenades and shots from available arms.**

PROCEDURES:—

1. **Obliterate all identifying marks. Destroy nameplates and circuit labels.**
2. **Demolish all panels, castings, switch-and instrument-boards.**
3. **Destroy all controls, switches, relays, connecting means and meters.**
4. **Rip out all wiring in electrical equipment. Smash gas, oil, and water cooling systems in gas-engine generators, etc.**
5. **Smash every electrical or mechanical part whether rotating, moving or fixed.**
6. **Break up all operating instruments such as keys, phones, microphones, etc.**
7. **Destroy all classes of carrying cases, straps, containers, etc.**
8. **Where possible, and time permits bury all debris or dispose of it in streams or other bodies of water.**

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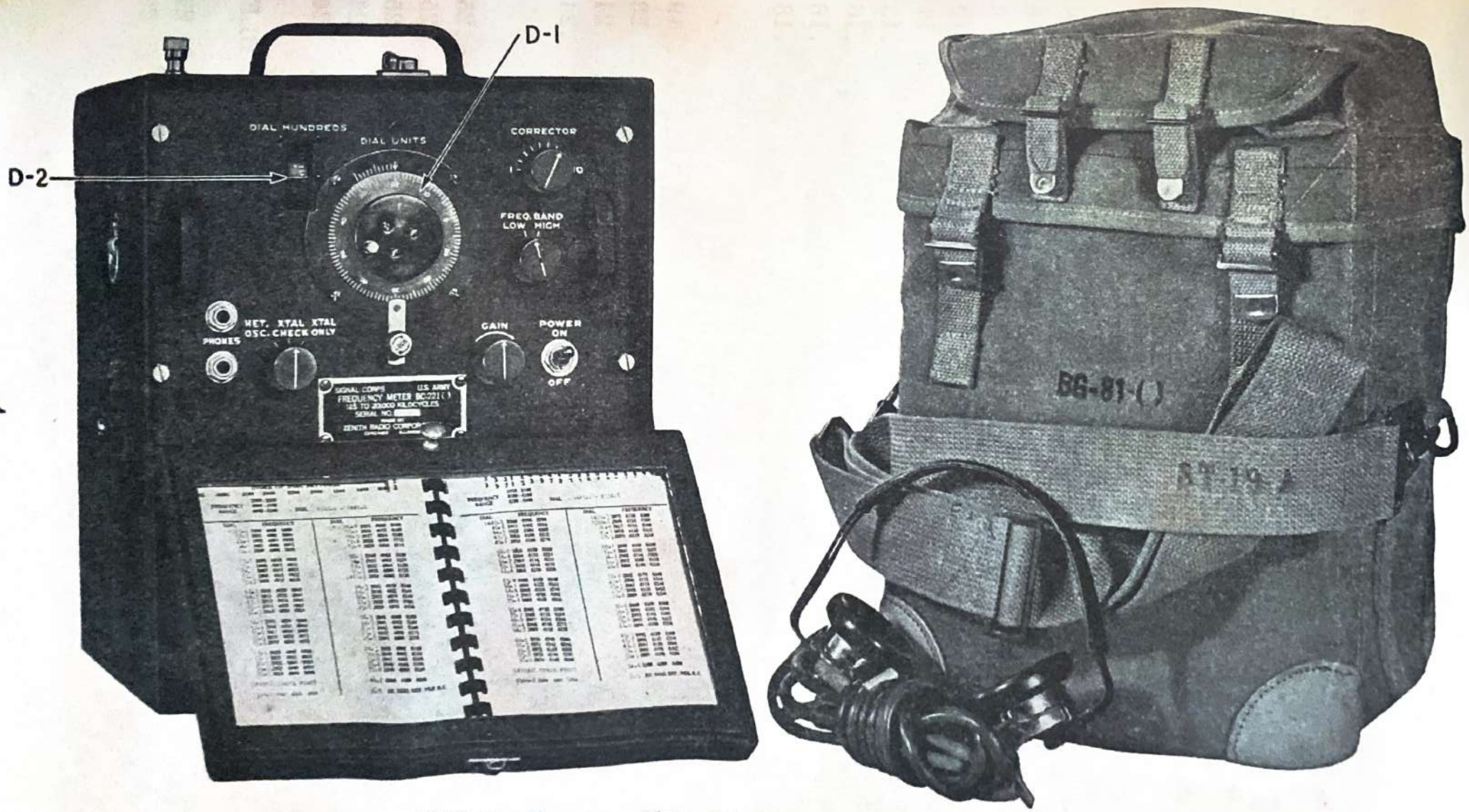

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PRELIMINARY INSTRUCTIONS
FREQUENCY METER SETS SCR-211-P AND SCR-211-T

1. DESCRIPTION

1. General. Frequency Meter Set SCR-211-( ) is a simple, accurate and reliable crystal calibrated frequency indicating instrument. The frequency range is 125 to 20,000 kc. The equipment provides accuracies of 0.01 per cent or 25 cycles, whichever is the greater, at any temperature in the range from minus 22 to plus 122 degrees F.

Note: With the exception of a slight difference in weight and size of the cabinet, Frequency Meter Set SCR-211-P and SCR-211-T are identical electrically and mechanically; therefore, all reference to nomenclature contained herein is shown with the suffix letter deleted, i. e. SCR-211-( ), BC-221-( ),DC-9-( ), etc. except where weight or size is indicated.

Frequency Meter BC-221-( ) contains a crystal controlled oscillator used as a reference standard; a heterodyne oscillator having two fundamental tuning ranges which, with their useful harmonics, are calibrated to provide continuous coverage from 125 to 20,000 kc; a high gain detector provided with means for coupling to each of three sources of excitation; and an audio frequency amplifier. There are seven operating controls: a POWER switch 29a-29b, which breaks both the filament and plate supplies; output PHONES jacks 15-1a, 15-2a with series filament supply switches 15-1b, 15-2b built integral therewith; OPERATION switch 28a, 28b which controls the crystal and heterodyne oscillators; a two position FREQuency BAND switch 27a thru 27e for the heterodyne oscillator; the heterodyne oscillator worm and gear tuning control together with its DIAL UNITS and DIAL HUNDREDS scales; the CORRECTOR control; and the output GAIN control 26. All of these controls are mounted on the front panel of the frequency meter chassis, which is completely housed within the upper compartment of a portable cabinet in which batteries and spare parts are also carried. An antenna plug 31 and the 3-contact power input plug 34, on the chassis, engage with corresponding jacks on the cabinet when the chassis is secured in place. The antenna jack 32 is connected directly to an antenna terminal post 33 on the top of the cabinet, and the power input jack 35

is connected through cabling to a battery terminal board 36 in a *lower* compartment. Provision is made for installing the batteries in this lower compartment, access to which may be had through a hinged door at the rear. Calibration Book MC-177-( ) is mounted within a dual hinged door assembly at the top front of the cabinet. This door covers the frequency meter panel when closed, and supports the calibration book at a convenient angle for use when opened. The spare set of vacuum tubes and special wrench for the #8 Bristo set screw used in the assembly of the equipment are stored in the spare parts compartment at the bottom front of the cabinet. A rigid carrying handle is welded on the top of the cabinet and, in addition, suitable fixtures are fastened to the sides to permit the use of a carrying Strap ST-19-A. The external surfaces are finished in a durable black wrinkle enamel. Figures 1 to 11, inclusive, show the general construction, arrangement of parts, and overall dimensions.

2. Components. Each Frequency Meter Set consists of the following component units:

Quantity	Component	Weight, Lbs.
1	Bag BG-81-( )	2.19
1	Frequency Meter BC-221-( ). (see fig. 11 for dimensions) *Includes:* 1 Calibration Book MC-177-( ); 1 Crystal Unit DC-9-( ) (in operating position); 1 Wrench for Bristo #8 set screw;	(see note 1)
2	Sets of vacuum tubes (1 each of VT-116(B), VT-116-B, and VT-167) (1 set in use, 1 spare set)	0.30
1	Strap ST-19-A	0.70
2	Preliminry Instruction Books	0.50

Note 1. { Frequency Meter BC-221-P weighs 18.0 lbs.
Frequency Meter BC-221-T weighs 21.5 lbs.

3. Additional Equipment Required. The following additional *equipment is* required to complete each Frequency Meter Set SCR-211-( ):

Quantity	Description
1	Headset P-18 or P-20
6	Batteries BA-2
4	Batteries BA-23

4. Total Weight. Frequency Meter Set SCR-211-P ready for service with one set of batteries installed, weighs 38.8 pounds.

Frequency Meter Set SCR-211-T ready for service with one set of batteries installed weighs 42.3 pounds.

5. **Power Consumption.** All power required for the operation of this equipment is supplied by the batteries listed in Par. 3. The current drains at the specified voltage limits are as follows:

Filaments: 5.4 to 6.0 Volts, 0.86 to 0.92 Amp.
Plates: 121.5 to 135.0 Volts, 0.015 to 0.017 Amp.

These values are typical for operation with the operation switch in the XTAL CHECK position, under which condition maximum plate current is drawn.

II. EMPLOYMENT

6. **Initial Procedure.** As shipped, Frequency Meter BC-221-( ) is enclosed within the carrying bag, and all vacuum tubes are inserted in their respective sockets and clamped. After unpacking, all compartments of the frequency meter cabinet should be thoroughly inspected for possible damage during shipment.

7. **Installation.** *a. Batteries.* This being portable equipment, no installation is required. However, the batteries necessary for its operation must be installed before the equipment can be made ready for use. The frequency meter chassis should be removed from the cabinet while the batteries are being connected.

Four Batteries BA-23 and six Batteries BA-2 are required. Open the battery compartment at the lower rear of the frequency meter cabinet. Loosen the binderhead screw on the right hand outer side in order to release the metal strap which secures the filament batteries. Insert the four Batteries BA-23 under the strap and push well forward, with their terminal posts facing to the rear of the cabinet. Before tightening the securing strap, hold the wiring harness in such a position that the two lugs of the main cables align with the A+ and A— B— terminals on the battery terminal board, and turn the four cells so that their terminal posts match up with the individual cell lugs on the harness (the eight terminals on the circumference of a circle—see Figures 5 and 13). Tighten the securing strap with the cells in this position. The six Batteries BA-2 should then be assembled in two layers of three each, with the top

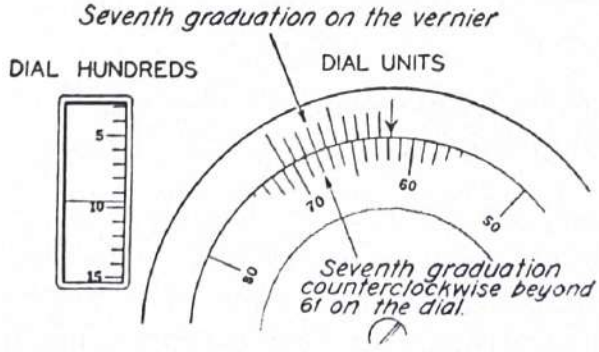
layer inverted (after interconnecting their respective terminal leads in series). See that the minus and plus 135-volt leads are free for connection to their respective terminals on the terminal board. Insert the batteries in the cabinet, connect them at the terminal board, and install the filament battery wiring harness.

Before replacing the frequency meter chassis, check the battery connections for 6- and 135-volt meter readings, respectively, at the battery terminal board.

b. Antenna. A short antenna must be provided for coupling to the receivers and transmitters which are to be adjusted. This should be a rigid wire, such as No. 12 B. & S. hard drawn bus, not over 3 feet long. This wire should be secured to the antenna terminal on the top of the frequency meter cabinet and so bent that its remote end will run parallel, and close, to the transmitter or receiving antenna lead. Where conditions will not permit this arrangement, such as in an airplane, a flexible insulated pick-up wire may be employed, with means provided to prevent its becoming a hazard during flight. One end should be skinned and secured to the antenna terminal on the frequency meter. Then, if the remote end is fitted with a completely taped test clip (jaws dulled), it will be possible to secure the lead at various coupling points, as desired, without grounding.

Caution: Never connect the frequency meter directly to a receiver or transmitter.

c. Headset. Plug a Headset P-18 in the PHONES jack; then turn the POWER switch ON and place the operation switch in the XTAL CHECK position. Allow the vacuum tube filaments to warm for at least 20 minutes, when the equipment will be ready for use.



8. Reading Dial. The drum behind the small window (D-2, fig. 1) indicates the reading of the dial setting in hundreds. The large

dial D-1 provides the units; and the vernier scale above and concentric with the large dial provides the tenths place of the setting. To read the vernier, find that line of the vernier scale which coincides most closely with a line of the large dial.

The number of this vernier line (counting the arrow as zero) gives the tenths place of the complete dial setting. The illustration on Page 9 shows the dial set for a reading of 0961.7. Before using the frequency meter for actual measurements, it is advisable to practice on the dial until settings can be established or read off quickly and accurately. It should be noted that on the large dial the line to the right of the arrow gives the proper value. If, for example, the dial is set at exactly 50 divisions and the vernier reads both 0 and 10 x .1 (ten tenths), the correct reading is 49 + 1.0 = 50, and not (50 + 1.0) = 51. The large dial is provided with a simple friction lock by means of which a predetermined setting can be kept fixed. This is particularly useful when the instrument is used in aircraft.

9. Operation. *a. Correcting to Calibration.* (1) Before attempting to make any frequency adjustments, the heterodyne oscillator should always be corrected to agree with the calibration through comparison with the crystal oscillator at the crystal check point nearest to the frequency desired. Comparison between the crystal and heterodyne oscillator may be made at many points over the calibrated range through the employment of the fundamental or harmonic frequencies of either or both oscillators. Comparison between the two oscillators is effected by rotating the heterodyne tuning control through a portion of the scale range corresponding to the crystal check point desired, and noting the beat tones as heard in a Headset P-18 when plugged into the PHONES jack.

(2) To correct the heterodyne oscillator preparatory to setting on any desired frequency within the calibrated range, proceed as follows:

(a) From the HIGH or LOW frequency indices on the front and rear covers of the calibration book, determine in which band the desired frequency is located, and set the FREQuency BAND switch to correspond.

(b) Also, from the frequency indices, ascertain on which page the desired frequency is listed, and turn thereto. The crystal check point nearest the desired frequency will be found noted in red at the bottom of this page, together with its dial setting.

(c) Set the heterodyne oscillator dials to agree with this crystal check point dial setting (POWER switch ON and operation switch in the XTAL CHECK position). A beat note will probably be heard in the phones, as a complete absence of beat note can result only from three possible conditions, i.e., when the heterodyne oscillator is exactly on calibration; when it is so far off calibration that the beat frequency is above audibility; and when the equipment is defective. However, if no beats are heard, either of the first two of these conditions may be determined by rotating the CORRECTOR dial to where the beats become audible, and noting the direction of change. If the third condition is the cause, no beats should be heard at any point in the complete heterodyne oscillator range.

(d) With the heterodyne oscillator dials on the desired crystal check point setting, the heterodyne oscillator frequency should be adjusted as close to the crystal oscillator frequency as possible, by rotation of the CORRECTOR dial only. After the operator has become familiar with the equipment, it will be found that this adjustment can be made to zero beat. This is possible because all "locking in" tendencies have been minimized, and characteristic "rushes" due to the rise and fall of the beat frequency peaks are aurally recognizable well below the lower limit of audible tone.

b. Accuracy of Calibration. When corrected as previously described, the heterodyne oscillator frequency will agree with the calibration (to within the reset accuracies stated in par. 1) throughout the range of frequencies to which this particular crystal check point applies, provided; that the ambient temperature does not vary by more than ±5°C; the filament voltage and plate voltage do not vary individually or collectively by more than ±10%.

10. Readjustment of Trimmer Capacitors. *a.* It may be found that the heterodyne oscillator cannot be corrected to agree with the

calibration as explained in Par. 9a, particularly if the frequency meter is being used in a locality where extremely high or extremely low condition of humidity prevails. Under such conditions, and then only, it becomes necessary to reset the heterodyne trimmer capacitors 3-1 and 3-2. Access to the trimmer adjusting screws may be had through the holes marked LOW and HIGH on the right hand wall of the frequency meter chassis after it has been removed from the cabinet (see Figure 9). The chassis should be conveniently placed on a firm foundation to the right and in front of the cabinet, and the respective power input plugs and jacks should be interconnected with laboratory test leads. A small screw driver will be required to make these adjustments, the necessary procedure being as follows:

(1) Place the unit in operation, with the FREQuency BAND switch set to the LOW frequency band. Allow at least ten minutes for warm-up before proceeding.

(2) Set the DIAL UNITS and DIAL HUNDREDS scales to agree with the reading given for 250 kc. on Page 27 of the calibration book. Set the CORRECTOR dial at midscale (4.5 divisions). Operation switch should be in the XTAL CHECK position.

(3) After making sure that the dials are set correctly as in (2), with a small screw driver rotate the LOW band trimmer (capacitor 3-1) toward the right, while listening in the phones, until the heterodyne oscillator is set to zero beat of a strong beat with the crystal calibrator.

(4) Check the ability of the corrector capacitor to reset to zero beat at all crystal check points listed on the back cover of the calibration book, proceeding as outlined in par. 9a.

(5) If the unit cannot be corrected at all crystal check points in the low band with the trimmer adjustment that was made with the CORRECTOR dial set at 4.5 for 250 kc. the processes outlined in (3) and (4) should be repeated, with the CORRECTOR dial set to 6 divisions for 250 kc.

(6) By thus progressing, a setting of the low frequency trimmer will be found where it will be possible with the corrector capacitor

to reset the unit to zero beat at all crystal check point readings given for the low band in the calibration book.

(7) Repeat the above described processes with the FREQuency BAND switch set to the HIGH frequency band and the DIAL UNITS and DIAL HUNDREDS scales set to agree with the reading given for 4000 kc. given on Page 71 of the calibration book. Set the HIGH band trimmer (capacitor 3-2) to the position where it is possible with the CORRECTOR capacitor to reset to zero beat at all crystal check points listed for the high frequency band.

11. Beat Point Identification. *a.* It was stated in par. 9*a*(1) that "comparison between the crystal and heterodyne oscillator may be made at many points over the calibrated range through the employment of the fundamental or harmonic frequencies of either or both oscillators." When correcting the heterodyne oscillator to calibration, it will be found that there are numerous beat points at various harmonic combinations which are not listed as crystal check points in the calibration book. In most cases, the intensity of these unlisted beat points is relatively low. In order that there may be no confusion as to the actual crystal check points, however, the beat points encountered at the various lowest harmonic combinations of the two oscillators (and the relative outputs for a typical Frequency Meter BC-221-( ), with 6.0 volt filament and 135.0 volt plate supplies, GAIN control set at maximum) are given in the following tabulation (the calibrated crystal check points are marked with asterisks):

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(1) Beat Point

Het. Fund Freq. (In Kilocycles) *(a) Low Band*	Lowest Het. Har.	Lowest Crystal Harmonic	Output Milliwatts
125.00*	8	1	29.0
128.21	39	5	0.4
129.03	31	4	2.6
130.43	23	3	7.6
131.57	38	5	1.0
133.33*	15	2	17.0
135.13	37	5	0.9
136.36	22	3	10.3
137.93	29	4	4.5
138.88	36	5	1.4
142.86*	7	1	32.0
147.05	34	5	1.5
148.14	27	4	5.3
150.00	20	3	15.9
151.51	33	5	3.6
153.85*	13	2	21.2
156.25	32	5	1.4
157.89	19	3	15.0
160.00	25	4	6.7
161.29	31	5	3.9
166.67*	6	1	34.0
172.41	29	5	3.8
173.91	23	4	6.9
176.47	17	3	16.9
178.57	28	5	2.9
181.82*	11	2	30.0
185.18	27	5	7.5
187.50	16	3	24.0
190.47	21	4	15.1
192.31	26	5	5.1
200.00*	5	1	36.0
208.33	24	5	7.5
210.53	19	4	15.6
214.29*	14	3	25.0
217.39	23	5	6.2
222.22*	9	2	28.5
230.77*	13	3	27.0
235.29	17	4	7.2
238.09	21	5	7.0
250.00*	4	1	34.5

EMPLOYMENT

Het. Fund Freq. (In Kilocycles) *(b) High Band*	Lowest Het. Har.	Lowest Crystal Harmonic	Output Milliwatts
2000*	1	2	43.0
2125	8	17	8.0
2143	7	15	14.0
2167*	6	13	19.0
2200	5	11	24.5
2250*	4	9	24.0
2286	7	16	9.0
2333*	3	7	31.0
2375	8	19	4.0
2400	5	12	22.5
2429	7	17	6.8
2500*	2	5	36.0
2571	7	18	6.8
2600	5	13	18.5
2625	8	21	3.0
2667*	3	8	29.0
2714	7	19	4.7
2750*	4	11	24.5
2800	5	14	17.0
2833	6	17	6.6
2857	7	20	3.6
2875	8	23	1.4
3000*	1	3	38.0
3125	8	25	1.6
3143	7	22	3.3
3167	6	19	6.0
3200	5	16	12.0
3250*	4	13	20.8
3286	7	23	2.4
3333*	3	10	25.5
3375	8	27	1.1
3400	5	17	8.5
3429	7	24	2.2
3500*	2	7	31.5
3571	7	25	1.4
3600	5	18	7.0
3625	8	29	.4
3667*	3	11	23.5
3714	7	26	1.5
3750*	4	15	12.5
3800	5	19	5.0
3833	6	23	1.9
3857	7	27	.6
3875	8	31	.2
4000*	1	4	40.0

EMPLOYMENT

12. Transmitter Adjustments. *a.* Briefly, the method of adjusting a transmitter to a desired frequency consists of zero beating the transmitter frequency with the proper heterodyne oscillator frequency, effecting the comparison by means of a headset plugged into the PHONES jack located on the front panel of the frequency meter. The operation switch should be in the HET. OSC. position during the process.

b. Specifically, the procedure is as follows:

(1) Correct the heterodyne oscillator to calibration at the crystal check point nearest to the desired frequency, as explained in par. 9*a*.

(2) Turn the operation switch to the HET. OSC. position.

(3) Turn the frequency meter tuning control to the dial setting of the desired frequency, as given in the calibration book. Do not disturb the CORRECTOR capacitor adjustment as made in (1) above.

(4) With the frequency meter antenna loosely coupled to the transmitter output, tune the transmitter to give an audible beat in the phones.

(5) Adjust the GAIN control to obtain a comfortable signal level in the headphones.

(6) Tune the transmitter to zero beat with the frequency meter.

(7) Note: For greater accuracy operation (2) to (6) should be accomplished in the shortest possible interval following operation (1), otherwise changes in voltage or temperature or both may cause the frequency meter to drift.

13. Receiver Adjustments. *a.* The method of adjusting a receiver to a desired frequency consists of tuning the receiver to the proper heterodyne oscillator output frequency, and effecting the comparison by means of a pair of headphones connected to the receiver output circuit. The method varies with the character of signal reception involved, as detailed in sub-sections (1) and (2) below:

(1) To tune a CW receiver to a desired frequency, proceed as follows:

EMPLOYMENT

(a) Correct the heterodyne oscillator to calibration at the crystal check point nearest the desired frequency as explained in par. 9*a*.

(b) Turn the operation switch to the HET. OSC. position and change over to another headset connected to the receiver output jack.

(c) Turn the frequency meter tuning control to the dial setting of the desired frequency, as given in the calibration book and lock the dial. Do not disturb the CORRECTOR capacitor adjustment as made in *(a)* above.

(d) With the frequency meter antenna loosely coupled to the receiver antenna lead, tune the receiver to give an audible signal.

(e) Adjust the receiver tuning to that side of zero beat which results in best reception conditions for the particular operator concerned.

(f) *Note:* The notation, par. 12*b*(7) applies to this and all other operations for which the frequency meter may be employed.

(2) To tune a MCW receiver to a desired frequency the following procedure applies:

(a) Correct the heterodyne oscillator to calibration at the crystal check point nearest to the desired frequency, as explained in par. 9*a*.

(b) Turn the frequency meter tuning control to the dial setting of the desired frequency, as given in the calibration book. Do not disturb the CORRECTOR capacitor adjustment as made in *(a)* above.

(c) Turn the operation switch to the HET. OSC. position.

(d) Adjust a local unmodulated transmitter (capable of being modulated) to zero beat with the frequency meter, proceeding as outlined in par. 12*b*(4), 12*b*(5), and 12*b*(6).

(e) Change over to another headset connected to the receiver output jack, modulate the transmitter output, and tune the receiver for maximum undistorted response.

EMPLOYMENT

14. Frequency Measurements. *a.* Frequency Meter Set SCR-211-( ) may also be employed for accurately measuring a frequency emitted from an external source, whether it be of local or remote origin, provided that such frequency lies within the calibrated range.

b. If it is desired to accurately measure the emitted frequency of an adjacent transmitter or oscillator, the frequency of which is approximately known, the heterodyne oscillator is first corrected to the crystal check point nearest to the approximately known frequency, as explained in par. 9*a*. The actual frequency is then determined (after loosely coupling the frequency meter antenna to the source and turning the operation switch to the HET. OSC. position) by turning the frequency meter tuning control to the zero beat point found nearest the setting given for the approximate frequency, and reading from the frequency column, opposite the resultant dial setting, in the calibration book.

c. If it is desired to accurately measure the emitted frequency of an adjacent transmitter or oscillator, the frequency of which is unknown, it may first be determined to an approximation most readily with the aid of an absorption type wave-meter, following which the actual frequency is determined as explained in par. 14*b*.

d. When it is desired to accurately measure a frequency of remote origin, the signal is first tuned in on a radio receiver, and the approximate frequency noted from the receiver calibration. The heterodyne oscillator is next corrected to calibration at the crystal check point nearest thereto. The operation switch is then turned to the HET. OSC. position and the frequency meter antenna loosely coupled to the receiver antenna lead and the frequency meter tuning control turned until its signal is heard in the receiver headset. If the signal in question is CW in character, the receiver is turned to zero beat, and the frequency meter is tuned to zero beat with the receiver. If the signal is modulated, the receiver is first adjusted for maximum response to the signal in the MCW condition, when it is changed over for CW reception and the frequency meter is tuned to zero beat therewith. In both cases, the frequency read from the appropriate column in the calibration book (for the resultant frequency meter dial setting) is the frequency of the signal in question.

FUNCTIONING OF PARTS

15. Circuits. *a.* The cathode, inner grid and anode grid of the Tube VT-167 (see Figures 12 and 13) constitute the active elements of the crystal controlled oscillator, which operates at the fixed frequency of 1000 kc. when the operation switch 28 is placed in the XTAL only position. The circuit is of a design which generates considerable harmonic energy in order that it may be employed to calibrate the heterodyne oscillator at several points over its entire range. The necessary plate circuit impedance is built up across an untuned inductance 18, which is thoroughly sealed against moisture. Likewise, the crystal 19 is supplied in a hermetically sealed and evacuated metal holder which provides permanent protection against humidity, corrosion and dirt intrusion. One of the smaller type metal tube envelopes is employed in the construction of this holder, so that it plugs into the standard octal tube socket 14 in mounting. The cut of the crystal and the internal construction of the holders are such that, under any conditions of barometric pressure, humidity, voltage, vibration, shock or tilt, only the specified output frequency and the harmonics thereof are obtained. The crystal is ground for operation at a normal temperature of plus 68°F. The temperature coefficient of the combined crystal, holder and circuit, as expressed in frequency shift is less than one cycle per degree F. as measured from —22°F. to +122°F.

b. Tube VT-116-B is used in an electron coupled circuit as the heterodyne oscillator (Figures 12 and 13). As previously stated, there are two continuously variable ranges which may be manually selected by the FREQuency BAND switch 27a thru 27e. In the low frequency position, a fundamental range of 125 to 250 kc. is employed; which, by calibrating the first, second, fourth and eighth harmonics, gives continuous coverage over the range from 125 to 2000 kc. In the high frequency position, a fundamental range of 2000 to 4000 kc. is employed; which, by calibrating the 1st, 2nd, 4th, and part of the 5th harmonics, gives continuous coverage throughout the range from 2000 to 20,000 kc. The two inductors 16 and 17, in the tuned circuits, are wound on ceramic forms and thoroughly sealed against moisture. Tuning over both fundamental ranges is

accomplished by a single variable capacitor 1, which is especially designed to have a low temperature coefficient, augmented by the variable corrector capacitor 2, and the adjustable low and high frequency trimmer capacitors 3-1 and 3-2, respectively. The main tuning capacitor 1 is capable of continuous rotation in either direction without stops, and the dial assembly includes a 100/1 ratio worm gear drive mechanism so that 50 revolutions of the "vernier" dial are required for 180° rotation of the main scale (on the capacitor shaft). The drum, or DIAL HUNDREDS, scale is engraved with 50 divisions over its useful 180° sector; and the vernier dial is marked with 100 DIAL UNITS divisions over the entire 360°. The arrangement thus provides 5000 effective readable divisions, of which the calibrated ranges occupy approximately that portion between 250 and 4750 (see figure 15). Backlash in the gear mechanism has been reduced to less than two-tenths of one division, and a dial lock is provided to prevent any accidental movement of the dial after the desired setting has been made.

c. The heterodyne oscillator circuits are calibrated from the crystal at a temperature of plus 68°F, and the dial settings of the successive harmonics (crystal check points) are noted along the calibration. The temperature coefficient of each range of the heterodyne oscillator, expressed in percentage of frequency, is less than 0.001 per cent per degree F, as measured over a range of 144°F. The corrector capacitor 2, which is connected in parallel with 1, makes it possible to reset the heterodyne oscillator to agreement with the crystal calibration at any harmonic for any ambient temperature between the limits of minus 22° and plus 122°F. Thus, after the tube filaments have been lighted for at least 20 minutes, and the heterodyne oscillator has been corrected to calibration at the nearest crystal check point, the heterodyne oscillator is capable of being reset to within 25 cycles or 0.01% of the absolute, whichever is the greater, for any frequency in the calibrated range.

d. It was previously stated that the three inner elements of Tube VT-167 are used in the crystal oscillator circuit. The remain-

ing elements of this tube (comprising the control grid, screen grid and plate) are used as a high gain screen grid detector; to which, by structure, the crystal oscillator is electronically coupled. The r-f voltage developed across the load resistor 21 in the plate output circuit of the electron coupled heterodyne oscillator is coupled to the control grid of this detector through a small fixed capacitor 5-1. The antenna plug 31, mounted on the chassis, is also coupled to the control grid of the detector, through the coupling capacitor 5-2 (in series with 5-1). As a result of these three coupling means, and dependent on the position of the operation switch, the detector functions to mix the heterodyne oscillator output either with the fundamental and successive harmonics of the crystal oscillator, or with the transmitter frequency to be measured. When the operation switch is thrown to the HET. OSC. position, the crystal oscillator is turned off. Variable air trimmer 50 is used to accurately adjust Crystal assembly 19 on original installation at the factory. Its adjustment must not be altered unless the instrument has been damaged, or if other than the original or spare Crystal assembly is employed. Under such circumstances it should only be adjusted by use of an extremely accurate external standard frequency of 1,000 kc.

e. The detector plate works into an audio choke 30, which is tuned by the capacitor 40-3, and the beat frequency voltages built up across it are coupled through capacitor 9 and the GAIN control potentiometer 26, to the grid of Tube VT-116(B). The grid of VT-116(B) returns to ground through the potentiometer 26, the desired bias potential being obtained by the drop in the cathode resistor 38-2. The plate of VT-116(B) returns to the positive plate supply through the load resistor 25, the latter being bypassed to ground through capacitor 45. The plate of VT-116(B) is also coupled to the PHONES jacks 15-1a, 15-2a, through capacitor 10, so that no d-c potentials are present in the output. The characteristics of the output circuit are such that either high-impedance (15,000 ohms) or low-impedance (2500 ohms) headsets may be used without any change-over adjustments being required.

f. The detector and audio amplifier combination is so designed that the output impressed across the phones is essentially a linear function of the input voltage for the output range of 1.0 to 6.00 milliwatts (beat frequency of 300 cycles). Regardless of whether the heterodyne oscillator is beating with energy from an external source of radio frequency or with the crystal calibrator, the output will vary with audio frequency as follows:

(1) Beat Note Frequency	Output
100 Cycles	10 Milliwatts
300 Cycles	15 Milliwatts
1000 Cycles	4 Milliwatts

g. It was previously stated that the antenna plug 31 is coupled to the control grid of the detector through capacitors 5-2 and 5-1 respectively, in series. By further reference to Figures 12 and 13, it will be seen that the antenna plug 31 is also coupled directly to the heterodyne oscillator output through capacitor 5-2 alone. Thus, the antenna post 33 serves the dual purposes of a detector input terminal for the measurement of frequencies of external origin and of a heterodyne oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, 2000 microvolts or more of radio frequency energy will be available between the antenna terminal and ground (the chassis) at any frequency within the calibrated range.

h. All power required for the operation of this unit is introduced through the battery terminal board 36. The common negative filament and negative plate battery leads are connected to the middle terminal thereof, which is grounded to the chassis. A fabricated wiring harness is provided for inter-cell and filament battery to terminal board connections. The section 29a of the POWER switch closes the positive 6-volt supply terminal (A+) to the vacuum tube filaments through auxiliary switches 15-1b, 15-2b (when the headset plug is inserted in either of the PHONES jacks); and section 29b connects the positive 135-volt supply terminal (B+) to all plate and screen circuits. Since the door assembly containing the cali-

bration book cannot be closed when the headset plug is in place, the A batteries cannot be inadvertently discharged when the set is decommissioned, even though the power switch is left in the ON position.

i. By reason of extreme refinements involving the type and design of the basic circuits, the relative arrangements of parts, character of intercircuit couplings, shielding, etc., the performance of this unit has been developed to a degree where no "locking in" will occur between the heterodyne oscillator and either source of r-f with which it may be coupled, at any difference or beat frequency down to 5 cycles per second in the low fundamental range or down to 50 cycles per second in the high fundamental range. Although the phones become rapidly less efficient in audibly reproducing beat tones below 100 cycles per second, characteristic "rushes" coincident with the rise and fall of the beat frequency pulses are aurally recognizable.

16. Vacuum Tubes. The vacuum tubes employed in this equipment, and their maximum operating characteristics, are shown in the following tabulation:

Reference:	**VT-116-B**	**VT-167**	**VT-116(B)**
Function:	**Heterodyne Oscillator**	**Crystal Osc. & Detector**	**AF Amplifier**
Type:	**Triple Grid Amplifier**	**Converter**	**Triple Grid Amplifier**
Signal Corps Type Nomenclature:	**VT-116-B**	**VT-167**	**VT-116(B)**
Nearest Com'l. Equivalent:	**6SJ7Y**	**6K8**	**6SJ7(Y)**
Base:	**Octal 8 pin**	**Octal 8 pin**	**Octal 8 pin**
Heater Voltage (E_f):	6.3V	6.3V	6.3V
Control Grid Voltage (E_{g1}):	—3.0V	—3.0V	—3.0V
Screen Voltage (E_{g2}):	100.0V	100.0V	100.0V
Plate Voltage (E_{p1}):	250.0V	250.0V	250.0V
Anode Grid Voltage (E_{p2}):		100.0V	
Heater Current (I_f):	300MA	300MA	300MA
Screen Current (I_{g2}):	0.8MA	6.0MA	0.8MA
Plate Current (I_{p1}):	3.0MA	2.5MA	3.0MA
Anode Grid Current (I_{p2}):		3.8MA	
Transconductance (S_m):	1650μMho	350μMho	1650μMho

FUNCTIONING OF PARTS

17. Calibration Book MC-177( ). The low frequency fundamental range of the heterodyne oscillator is calibrated at each one-tenth kilocycle between 125 and 250 kc, or a total of 1251 points. Likewise, the high frequency fundamental range is calibrated in increments of one kilocycle between 2000 and 4000 kc, or a total of 2001 points. These fundamental frequencies are printed in columnar formation on the successive pages of the calibration book, together with associated columns listing the second, fourth and eighth harmonics thereof for the low range, and the second, fourth, and portions of the fifth harmonics for the high range. The dial settings, as determined by individual calibration, are then typed in opposite each such group. The nearest crystal check points are also shown in red across the bottom of each page and the first and last frequencies and dial settings tabulated thereon are indicated across the top. There are 72 inside pages, thumb tabbed as to page number. Page 28 is an index to the dial settings in the low range and page 31 contains a similar listing for the high range. In addition, an index of frequencies in the high range is printed on page 30, and another for the low frequency range is given on page 29. A brief summary of the essential steps in operating the equipment is given on page 72. The calibration is printed on high quality white rag index paper which is both oil and waterproof. The calibration book has two sheet metal covers, each of which is fitted with three threaded metal inserts for securing the book in open position within the door assembly of the frequency meter cabinet. A plastic type of binding is employed, so that the book lies flat when opened to any page.

The calibration book should be carefully preserved, as the cost of duplication constitutes an appreciable percentage of the total cost of equipment.

18. Bag BG-81-( ). The carrying bag is designed to include all components of Frequency Meter Set SCR-211-( ). It is fabricated from hard texture olive-drab duck, the bottom being felt

padded and the inner and outer walls reinforced with pigskin at the wear-points. The top is hinged at the rear, with overhanging sides and front to exclude dust and precipitation. This cover is fitted with webbing straps so that it may be conveniently secured by buckles on the front of the bag, and a similarly secured pocket is provided on the top for a Headset P-18. Suitable rings are secured with webbing to each side of the bag, to which an adjustable Strap ST-19-A may be attached.

IV. MAINTENANCE

19. General. Frequency Meter BC-221-( ) is ruggedly constructed to withstand the shocks and strains which may be expected in military service. Nevertheless, this equipment is extremely accurate and sensitive, and is therefore deserving of the careful handling normally accorded to instruments of precision.

20. Inspection. See Paragraph 6.

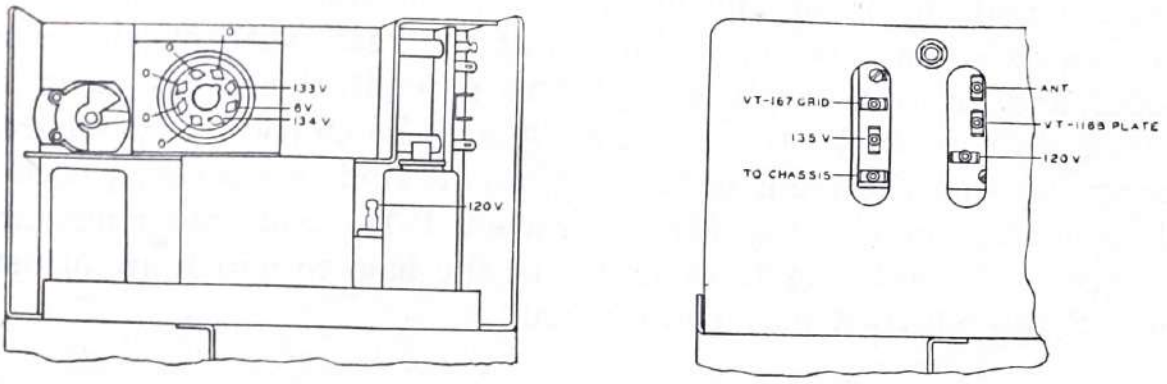
21. Servicing. Normally, the only servicing required should be the replacement of batteries and vacuum tubes. This should be done at regular intervals, dependent on the amount of usage to which the equipment is subjected. It is further recommended that a single drop of Pioneer Ball Bearing Oil for Aircraft Instruments No. 2 or equal be placed on the gear teeth of the heterodyne oscillator capacitor driving mechanism occasionally. Do not lubricate any other part of the equipment.

22. Resistors. The insulated resistors supplied in this equipment are marked in accordance with the RMA Standard Color Code. The color of the end stripe indicates the first figure of the resistance value, the second stripe indicates the second figure and the third stripe indicates the numbers of ciphers to follow the first two figures:

Color	Figure	Color	Figure
Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Gray	8
Yellow	4	White	9

The silver stripe indicates tolerance of $\pm 10\%$.

23. Socket Voltages.



VT-116B Voltages measured from top of socket—Tube removed.

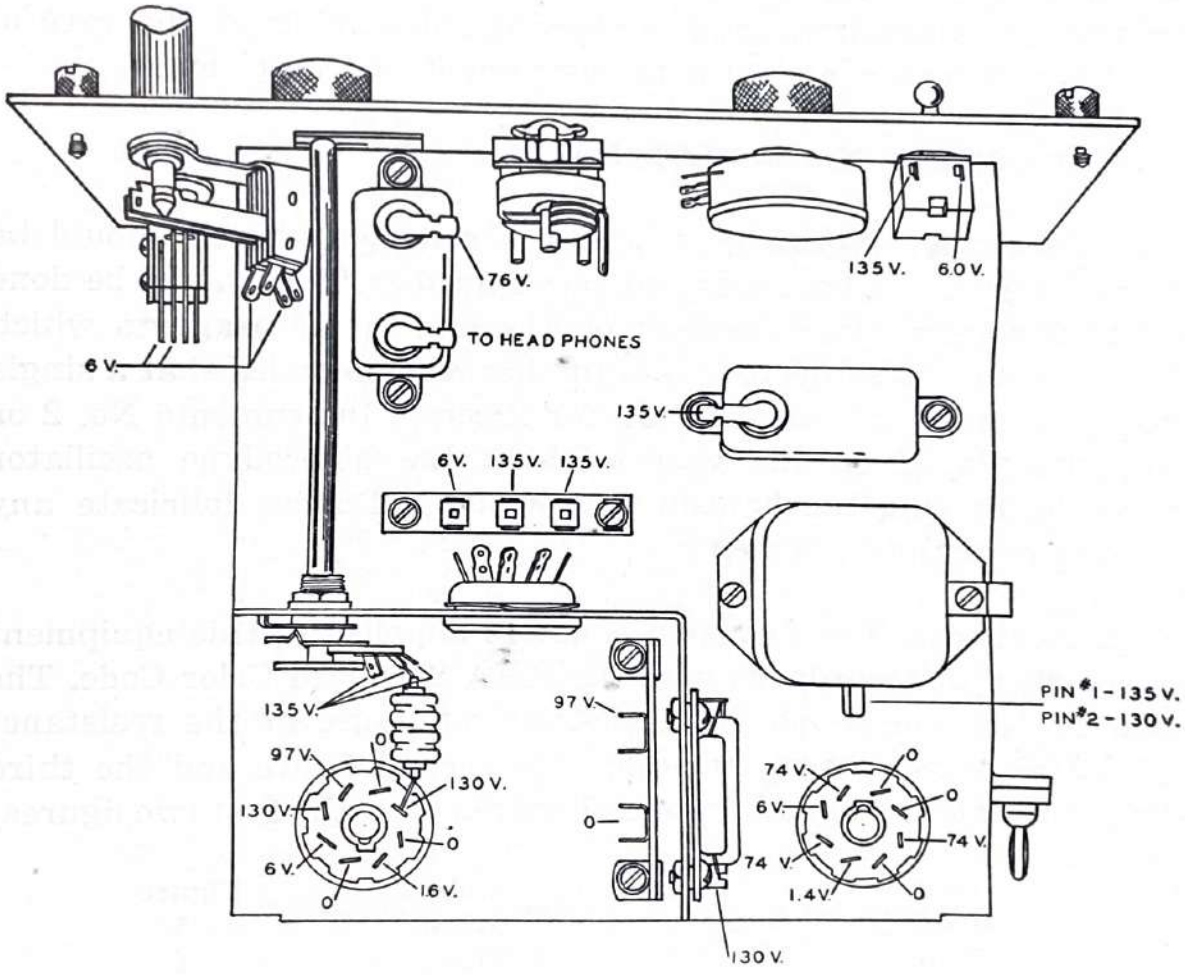


FIGURE 2—Tube Operating Voltages

24. Table of Replaceable Parts.

V. SUPPLEMENTARY DATA AND LIST OF REPLACEABLE PARTS

Ref. No.	Stock No.	Description	Mfrs. Type No.	Function	Mfr.	Zenith Part No.
1		Capacitor, Variable, 160 $\mu\mu f$	Special	Osc. Tuning	T	22G186
2		Capacitor, Variable, 3 $\mu\mu f$	AT	Corrector	Q, R, Y	22G9
3-1		Capacitor, Variable, 10 $\mu\mu f$	AT	Trimmer, L-F	Q, R, Y	22G5
3-2		Capacitor, Variable, 10 $\mu\mu f$	AT	Trimmer Hi-F	Q, R, Y	22G5
5-1		Capacitor, 10$\mu\mu f$ ±20% 500v Mica	5W	Osc. Coupling	E (Note 1)	22G6
5-2		Capacitor, 10$\mu\mu f$ ±20% 500v Mica	5W	Antenna Coupling	E (Note 1)	22G6
6		Capacitor, thermal, 7 $\mu\mu f$	811	Compensator, Lo-F	C	22G14
7		Resistor, 180 ohms ½ watt ±10%	BT	Cathode Bias	K, Z	63G23
9		Capacitor, 0.02 μf ±20% 300v Paper	342	Audio Coupling	N	22G478
10		Capacitor, 0.5 μf ±20% 200 volts	XD	Audio Output Coupling	S	22G3
11		Tube socket, octal ceramic	S	VT-116-B Socket	B	78G4
12		Tube socket, octal	S	VT-167 Socket	B, A1	78G2
13		Tube socket, octal	S	VT-116B Socket	B, A1	78G2
14		Crystal socket, 8 contact	S	Crystal Socket	B, A1	78G2
15-1a, b		Headphone jack	703	Phone jack, fil. switch	M, A4 (Note 4)	44G1
15-2a, b		Headphone jack	703	Phone jack, fil. switch	M, A4 (Note 4)	44G1
16		Oscillator inductance, Hi-F	Special	Het. Osc. Inductance	T	SG573
17		Oscillator inductance, Lo-F	Special	Het. Osc. Inductance	T	SG12
18		R-f choke coil assembly	Special	Crystal Plate Choke	T	SG538
19		1000 K.C. crystal assembly	DC 9	Crystal Oscillator	F, V, W	103G6
20		Resistor, 5,000 ohms ½ watt ±10%	BT	R-f Output Terminating	K, Z	63G6
21		Resistor, 50,000 ohms ½ watt ±10%	BT	Heterodyne Plate	K, Z	63G4
22-1		Resistor, 8,750 ohms ½ watt ±10%	BT	Het. Osc. Screen	K, Z	63G8
22-2		Resistor, 8,750 ohms ½ watt ±10%	BT	Det. Screen	K, Z	63G8
23-1		Resistor, 1 megohm ½ watt ±10%	BT	Crystal Osc. Grid Leak	K, Z	63G7
23-2		Resistor, 1 megohm ½ watt ±10%	BT	Detector Grid Leak	K, Z	63G7
24		Cathode Choke Coil Assembly	Special	Cathode Choke	T	SG529

SUPPLEMENTARY DATA AND LIST OF REPLACEABLE PARTS (Continued)

Ref. No.	Stock No.	Description	Mfrs. Type No.	Function	Mfr.	Zenith Part No.
25		Resistor, 15,000 ohms ½ watt ±10%	BT	Audio Plate Load	K, Z	63G2
26		Potentiometer, 500,000 ohms, 1 watt, ±10%	Radiohm	Gain Control	C	63G1
27a,b,c,d,e		Switch, Rotary, Special	QHC	Range Switch	Q	85G14
28a, b		Switch, Rotary, Special	TW	Crystal On-Off	C	85G15
29a, b		Switch, toggle	81009	Power On-Off	I	85G1
30		Choke, 450 Henries +20%,—10%	7477	Choke, Det. Plate	D, A3	95G1
31		Single Contact Plug	Special	Antenna Plug	G	58G3
32		Contact Spring	Special	Antenna Terminal	T	80G1
33		Terminal Post Assembly	Special	Antenna Terminal	L	8G1
34		Plug, 3 Contact	Special	Power Input	T	SG4
35		Jack, 3 Contact	Special	Power Input	T	SG26
36		Terminal Board, 3 Contact	Special	Battery Connector	T	SG24
37		Resistor, 4500 ohms ½ watt ±10%	BT	Het. Osc. L.F. cathode	K, Z	63G11
38-1		Resistor, 350 ohms ½ watt ±10%	BT	Het. Osc. H.F. cathode	K, Z	63G10
38-2		Resistor, 350 ohms ½ watt ±10%	BT	Audio cathode	K, Z	63G10
39		Resistor, 150,000 ohms ½ watt ±10%	BT	Osc. Grid	K, Z	63G9
40-1		Capacitor, .001 μf ±20% 500v Mica	O	Filament By-pass	E, N	(Note 2) 22G17
40-2		Capacitor, .001 μf ±20% 500v Mica	O	Det. Screen	E, N	(Note 2) 22G17
40-3		Capacitor, .001 μf ±20% 500v Mica	O	Det. Plate	E, N	(Note 2) 22G17
41		Grid Clip	Special	VT-167 Grid	O	19G3
42		Capacitor, 100 $\mu\mu f$, ±20% Mica	810	Grid Coupling	E	(Note 3) 22G16
43		Capacitor, 10 $\mu\mu f$, ±1 $\mu\mu f$, Ceramic	811	Compensator	C	22G187
44		Capacitor 0.1 μf 200v Paper +14%,—6%	XD	Het. Osc. Screen By-pass	A, S	22G127
45		Capacitor 0.7 μf 200v Paper, +14%—6%	XD	Audio Screen By-pass	S	22G128
46		Triple Grid Tube, VT-116-B	6SJ7Y	Heterodyne Osc.	J, A5	100G3
47		Converter Tube, VT167	6K8	Crystal Osc. and Det.	J, A5	100G27
48		Triple Grid Tube, VT-116	6SJ7	Audio Amplifier	J, A5	100G55
49		Capacitor, 6 $\mu\mu f$ ±½ $\mu\mu f$ Ceramic	812	Fixed Crystal Shunt	C	22G151
50		Capacitor, Variable 14.5 $\mu\mu f$	AT	Variable Crystal Shunt	Q, U, Y	22G150

Note 1—22G496 10 $\mu\mu f$ Ceramic may be substituted.
Note 2—22G492 .001 μf Mica or 22G499 .001 μf moulded paper may be substituted.
Note 3—22G495 100 $\mu\mu f$ Ceramic may be substituted.
Note 4—44G14 Jack m'f'd by A2 may be substituted.

25. Addresses of Manufacturers.

Mfr.	Name	Address
A	Aerovox Corporation	New Bedford, Mass.
B	American Phenolic Corp.	500 So. Throop St., Chicago, Ill.
C	Centralab	900 Keefe Ave., Milwaukee, Wis.
D	Chicago Transformer Corp.	3501 Addison St., Chicago, Ill.
E	Cornell-Dubilier	100 Hamilton Blvd., South Plainfield, N. J.
F	General Electric Co.	1 River Road, Schenectady, N. Y.
G	General Eng. Work	4701 W. Division St., Chicago, Ill.
H	Guthman Co., Inc.	400 So. Peoria St., Chicago, Ill.
I	Arrow-Hart and Hegeman	Hartford, Conn.
J	Hygrade Sylvania Corp.	Emporium, Penn.
K	International Resistance Co.	401 N. Broad St., Philadelphia, Penn.
L	E. F. Johnson Co.	Waseca, Minn.
M	P. R. Mallory & Co.	3029 E. Washington St., Indianapolis, Ind.
N	Micamold Radio Corp.	1087 Flushing Ave., Brooklyn, N. Y.
O	National Company	Malden, Mass.
P	National Fabricated Products	2650 W. Belden Ave., Chicago, Ill.
Q	Oak Manufacturing Co.	711 W. Lake St., Chicago, Ill.
R	Radio Condenser Co.	4449 W. Armitage Ave., Chicago, Ill.
S	Solar Mfg. Corp.	Bayonne, N. J.
T	Zenith Radio Corp.	6001 Dickens Ave., Chicago, Ill.
U	F. W. Sickles Co.	Springfield, Mass.
V	Bliley Electric Co.	Erie, Penn.
W	Bendix Radio Co.	Baltimore, Md.
X	Rauland Corp.	Chicago, Ill.
Y	American Steel Package	Defiance, Ohio
Z	Allen-Bradley Co.	Milwaukee, Wis.
A1	Cinch Mfg. Co.	Chicago, Ill.
A2	Chicago Telephone Supply Co.	Elkhart, Ind.
A3	Standard Transformer Corp.	Chicago, Ill.
A4	Utah Radio Products	Chicago, Ill.
A5	R.C.A. Radiotron	Harrison, N. J.

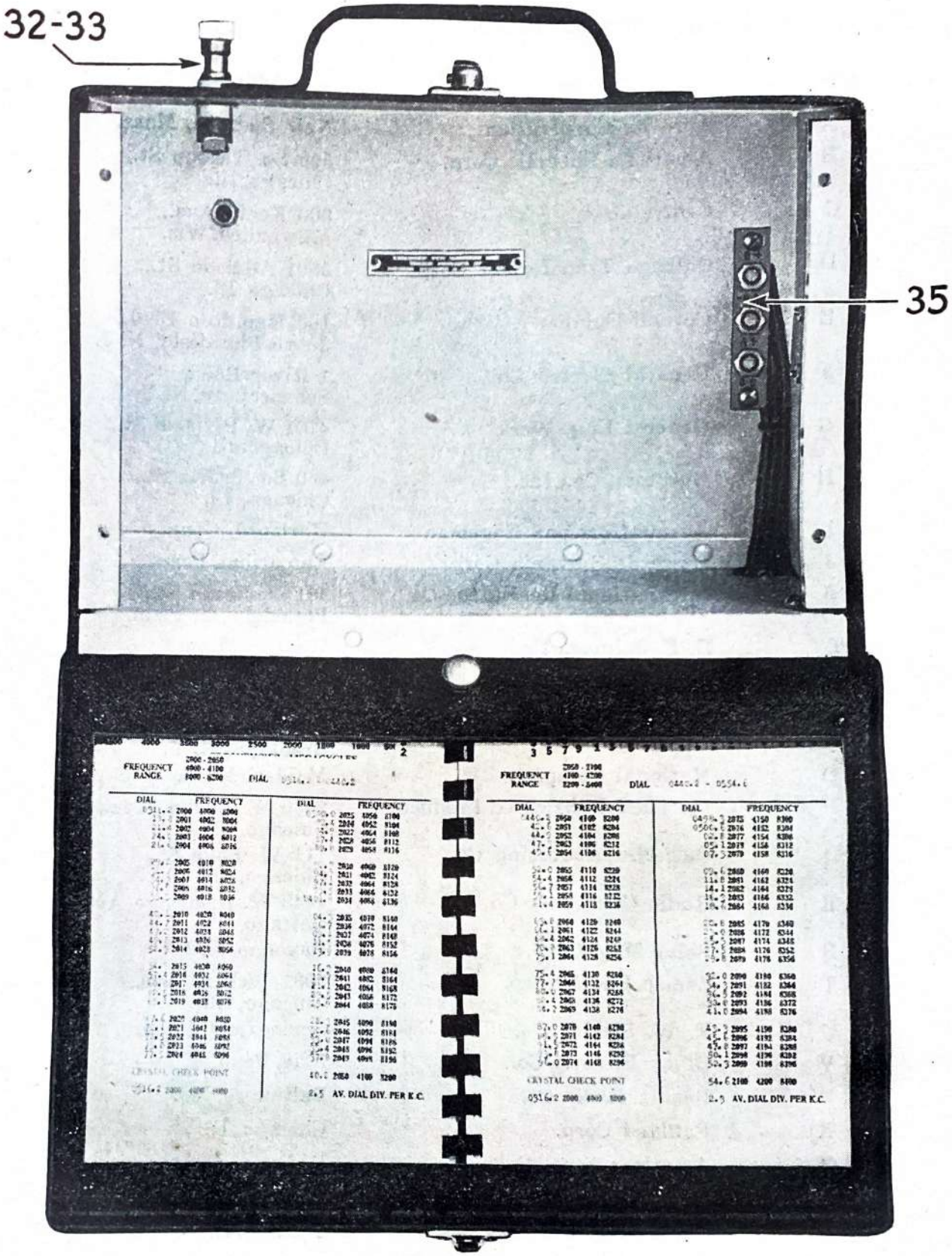


FIGURE 3—Frequency Meter BC-221-( ), Front of Cabinet, Chassis Compartment

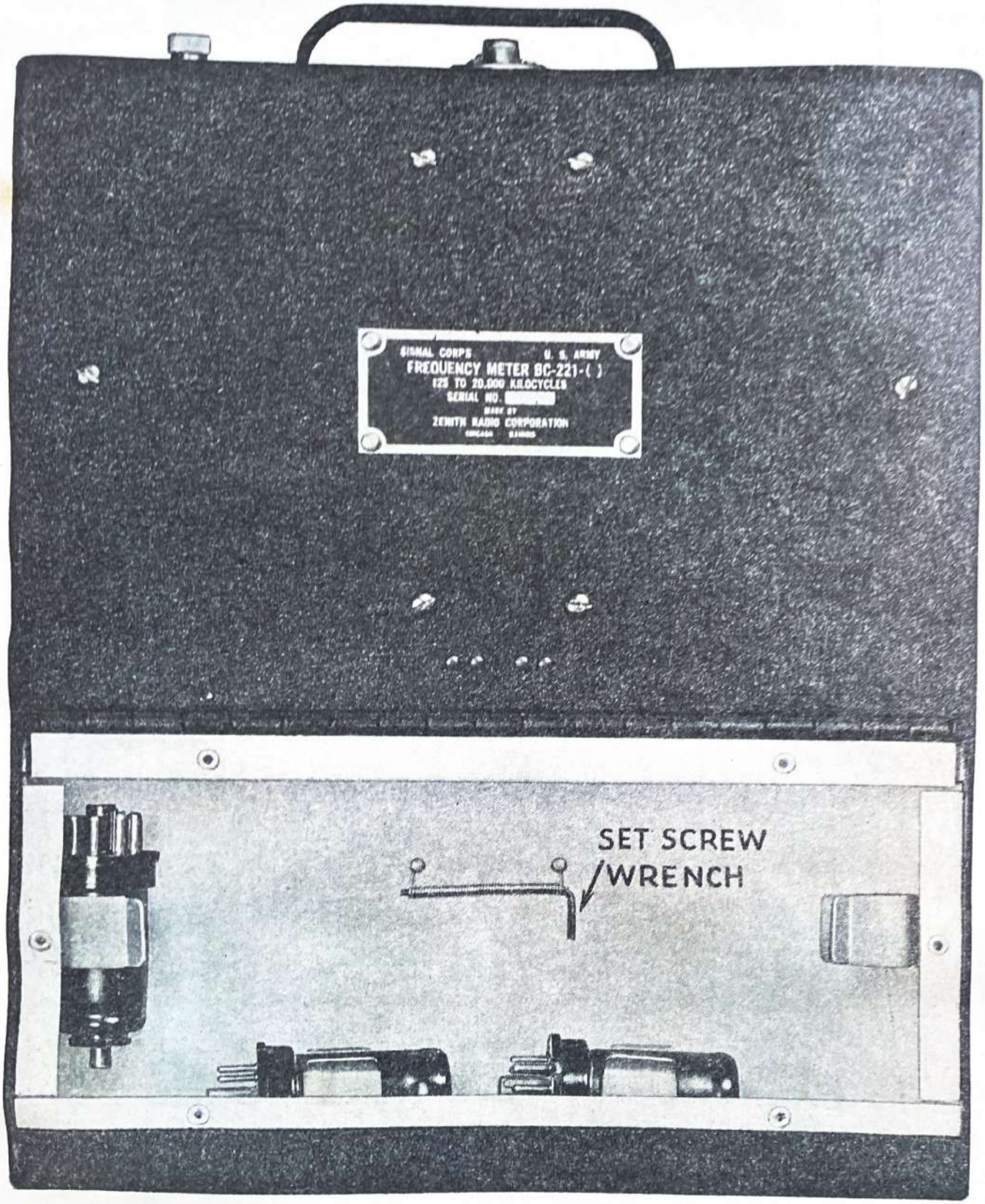


FIGURE 4—Frequency Meter BC-221-( ), Front of Cabinet, Spare Parts Compartment

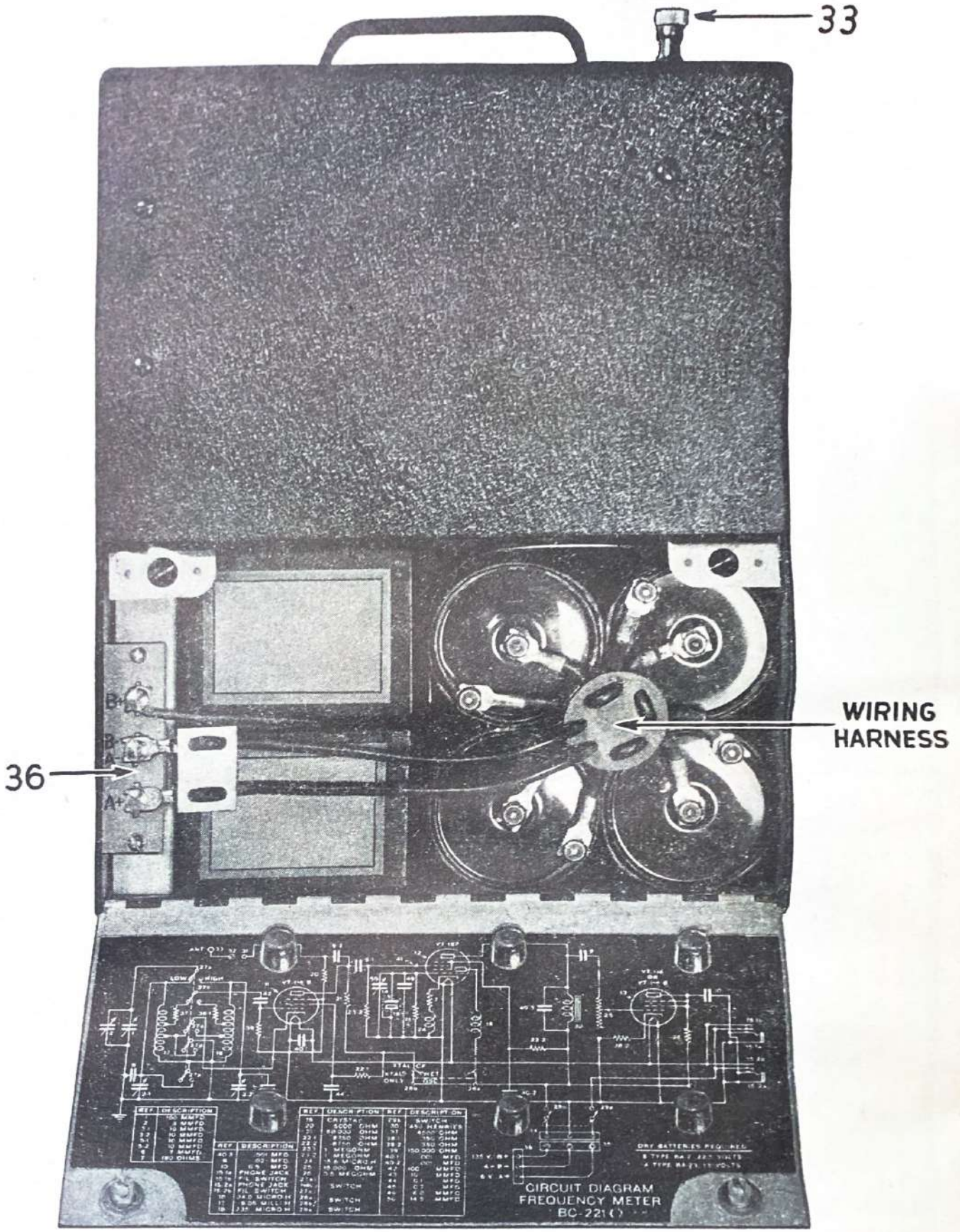


FIGURE 5—Frequency Meter BC-221-( ), Rear of Cabinet, Battery Compartment

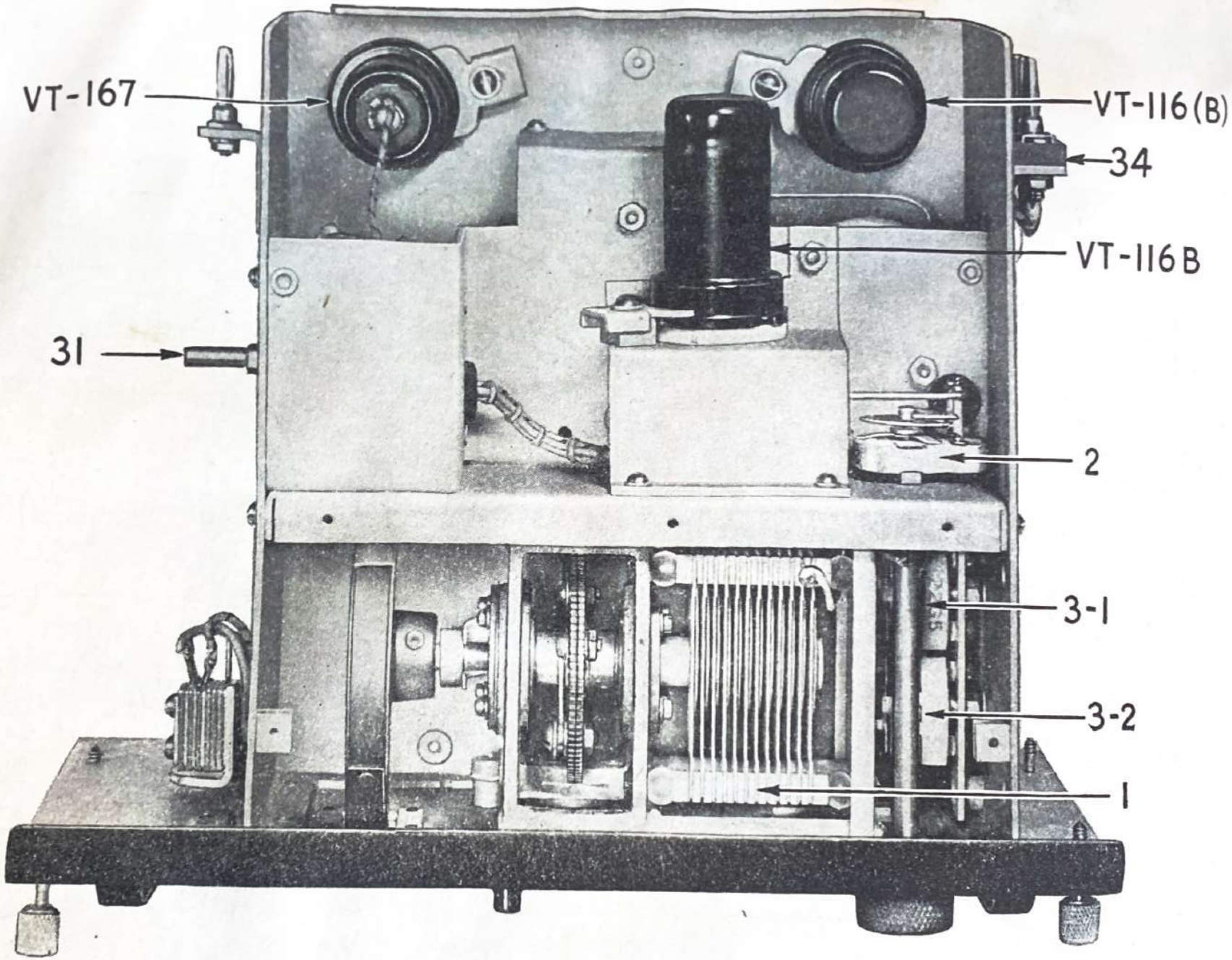


FIGURE 6—Frequency Meter BC-221-( ), Top View of Chassis, Condenser Shield Removed

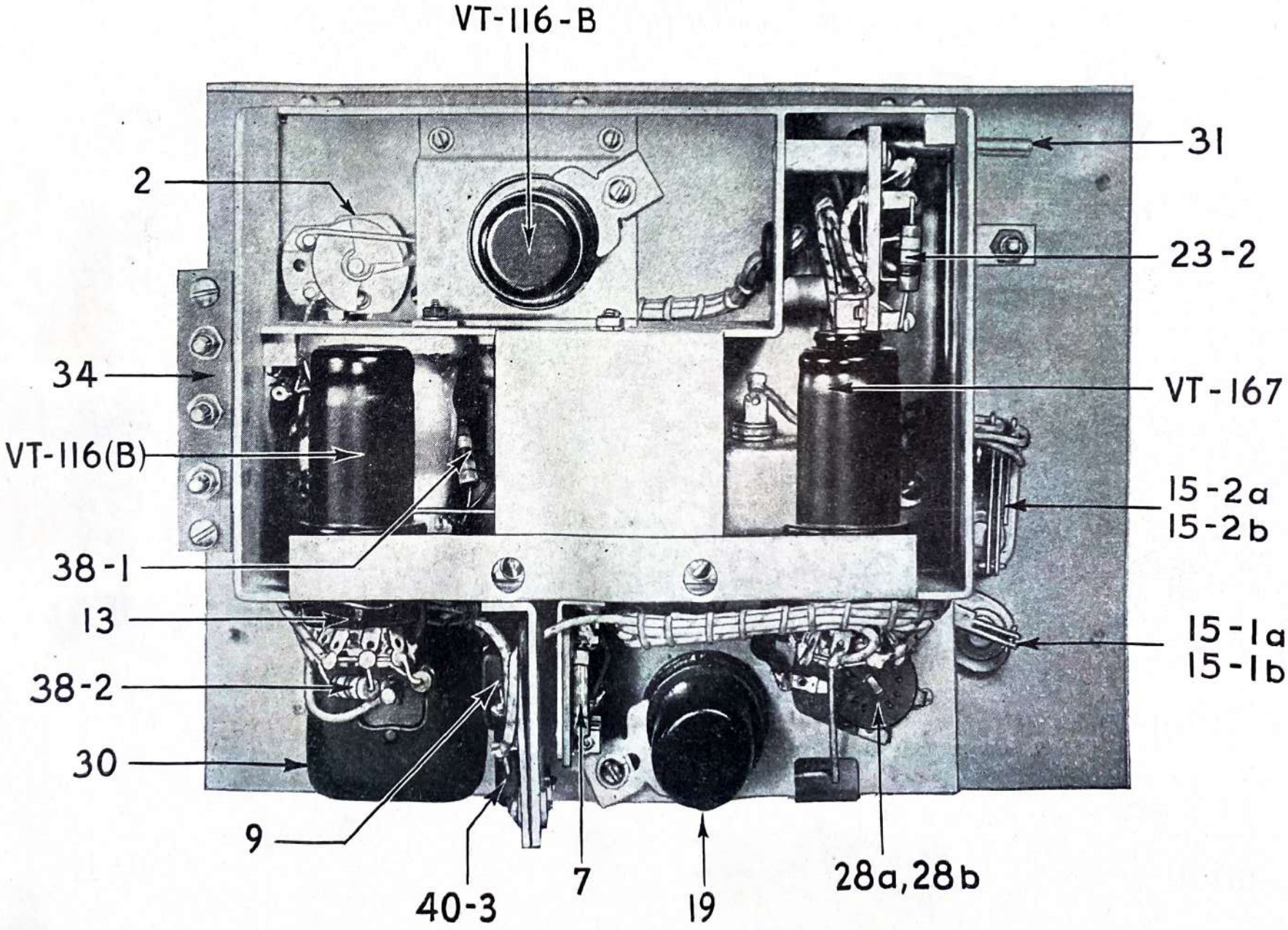


FIGURE 7—Frequency Meter BC-221-( ), Rear View of Chassis

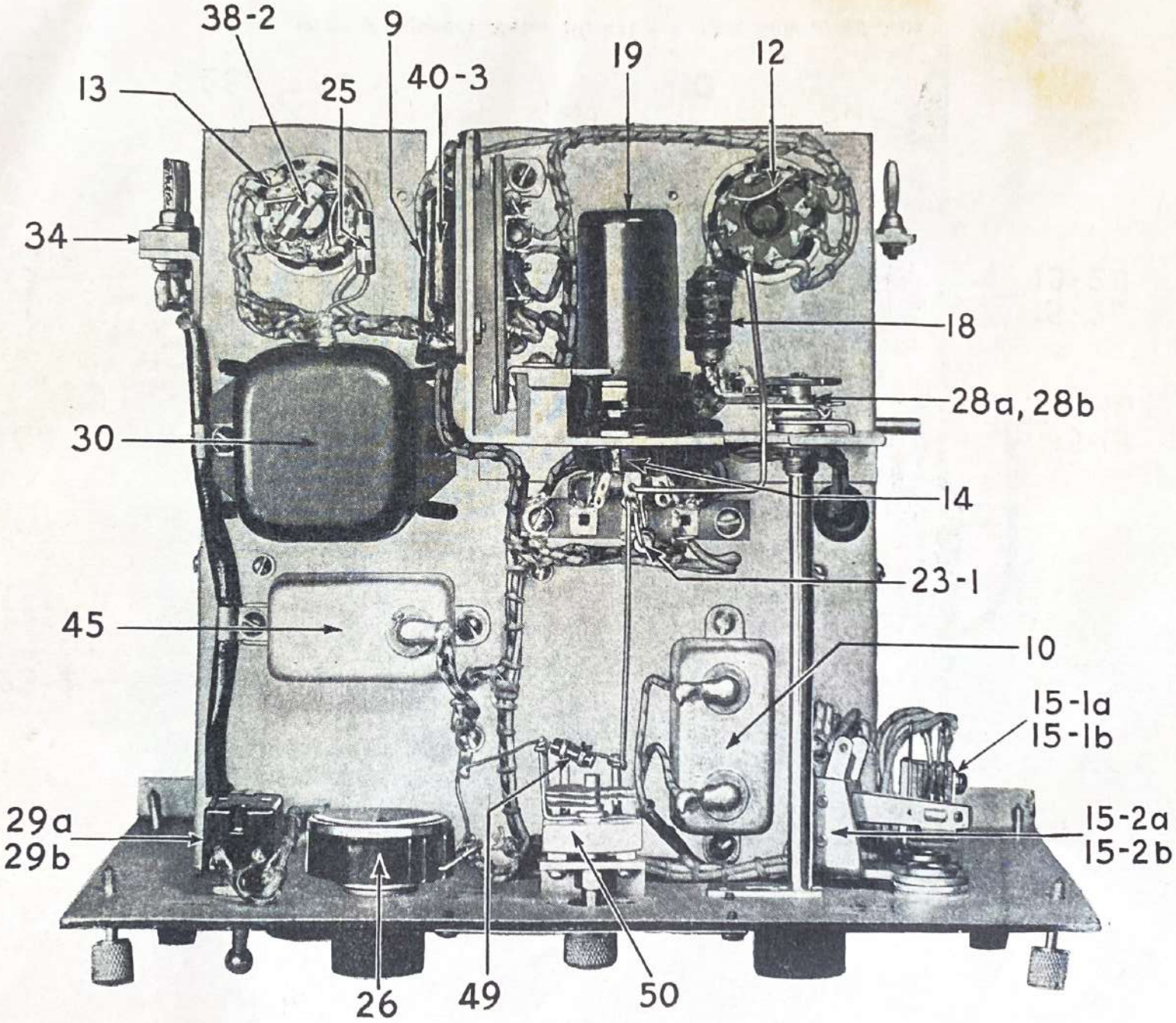


FIGURE 8—Frequency Meter BC-221-( ), Bottom View of Chassis

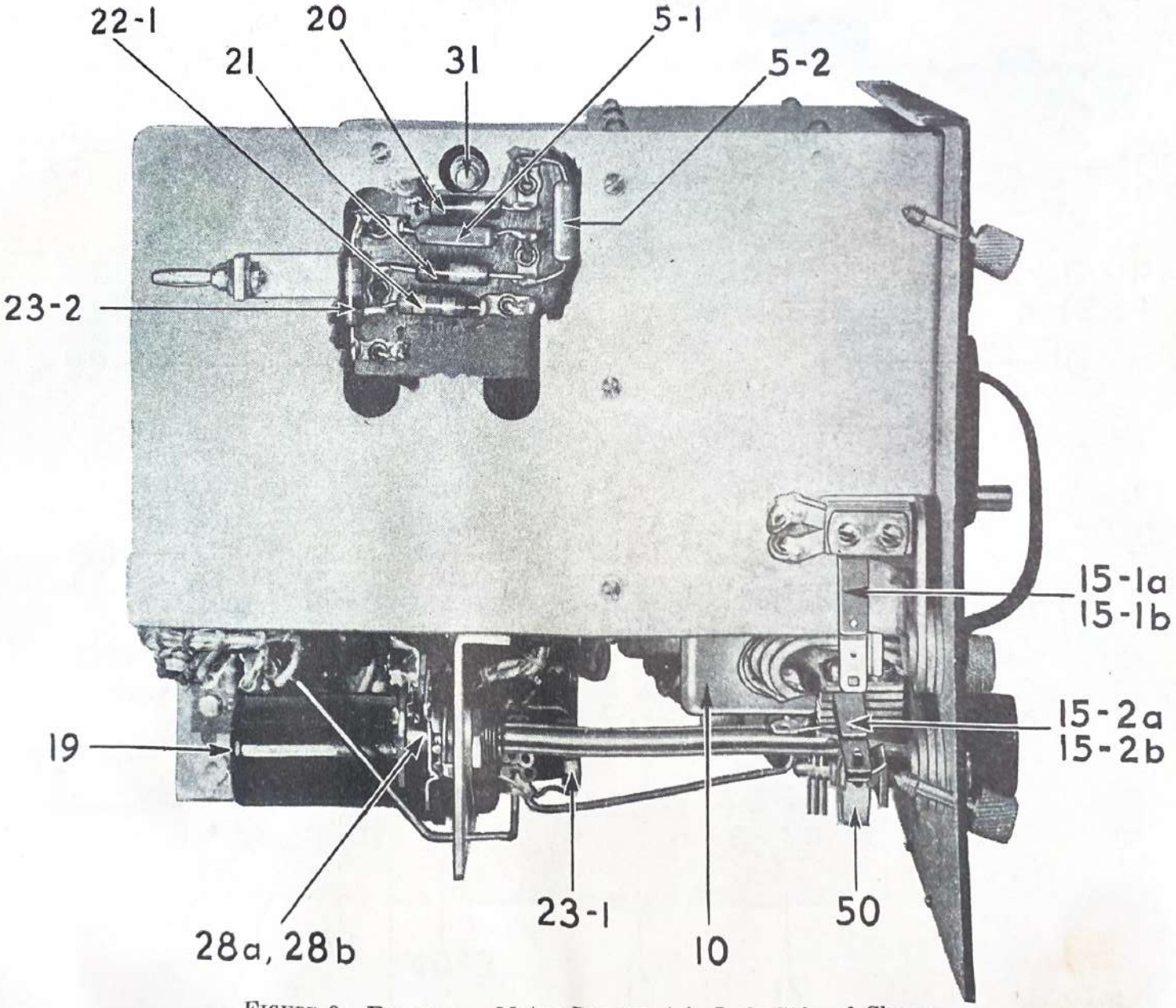


FIGURE 9—Frequency Meter BC-221-( ), Left Side of Chassis

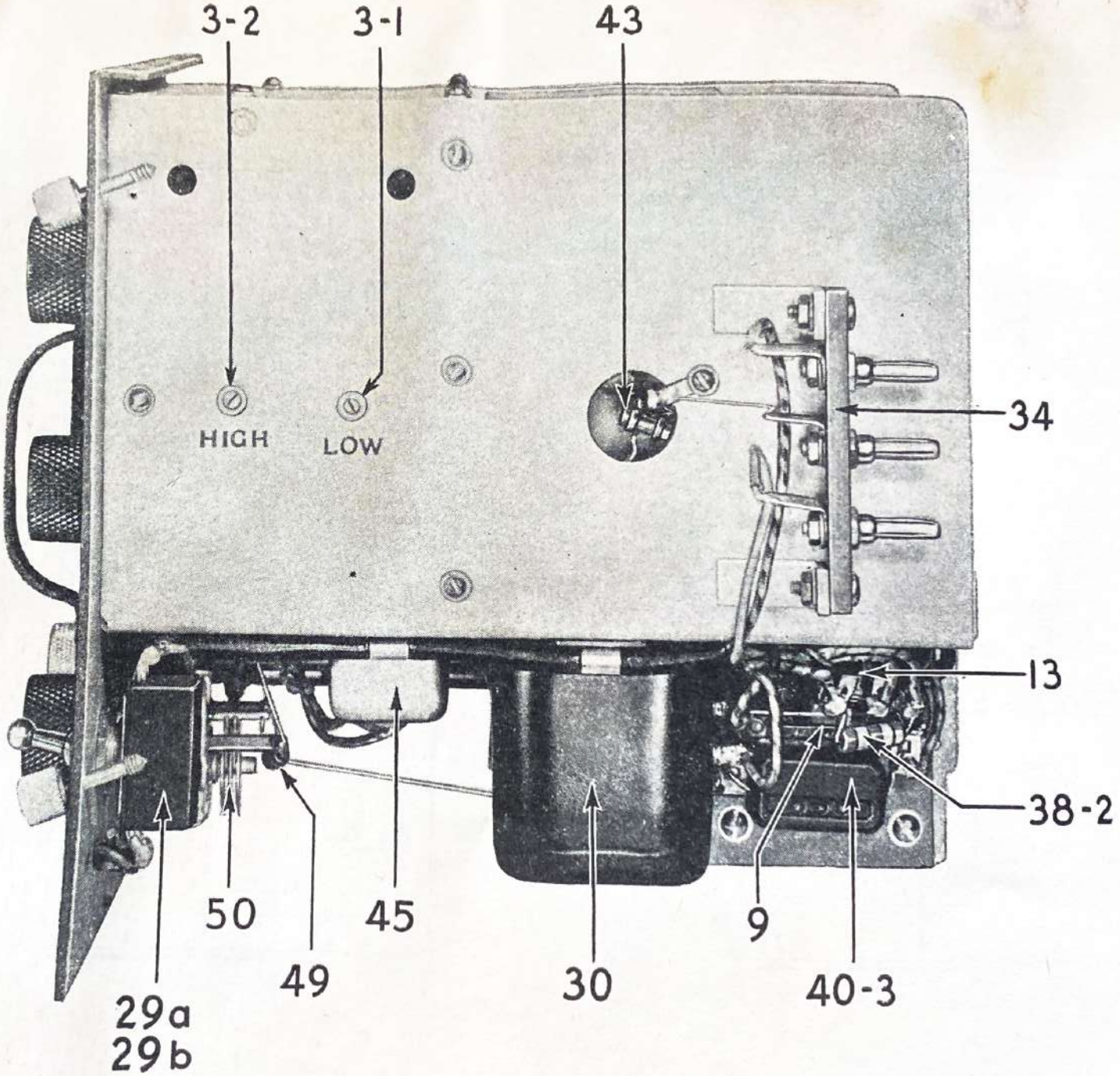
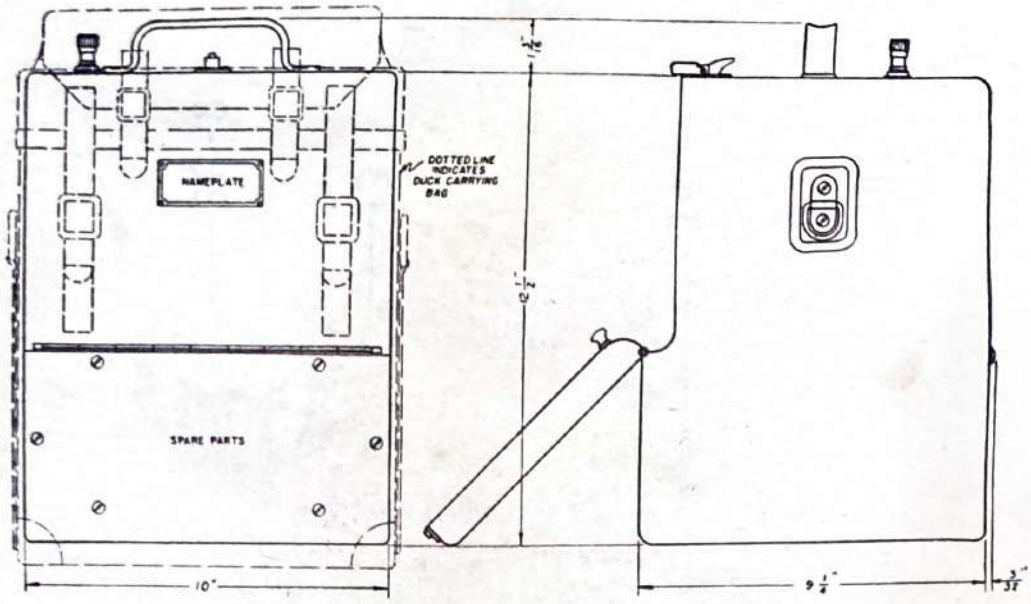
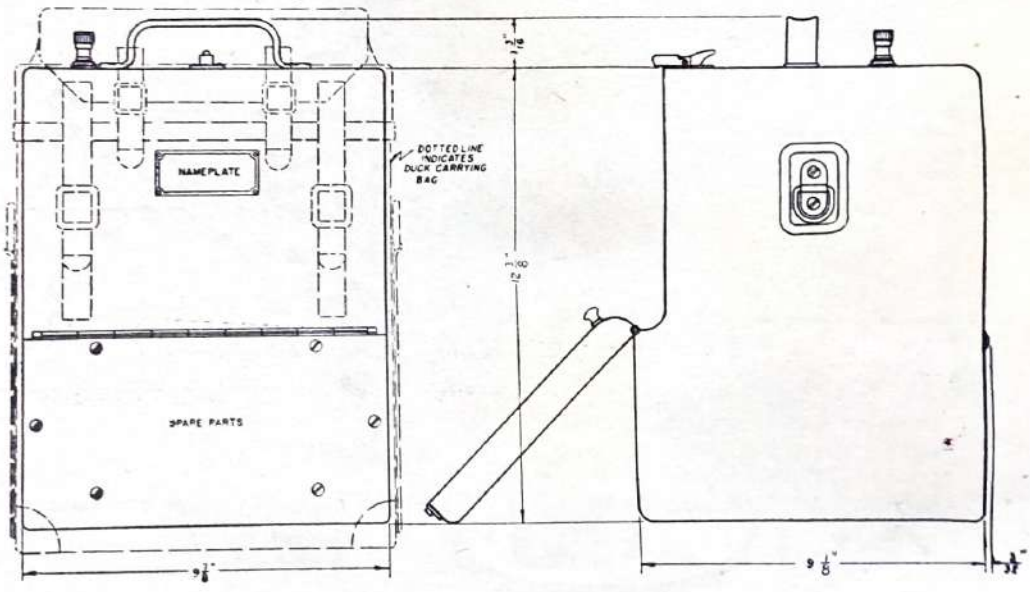


FIGURE 10—Frequency Meter BC-221-( ), Right Side of Chassis



Frequency Meter Set SCR-211-P, Outline Dimensions



Frequency Meter Set SCR-211-T, Outline Dimensions

FIGURE 11

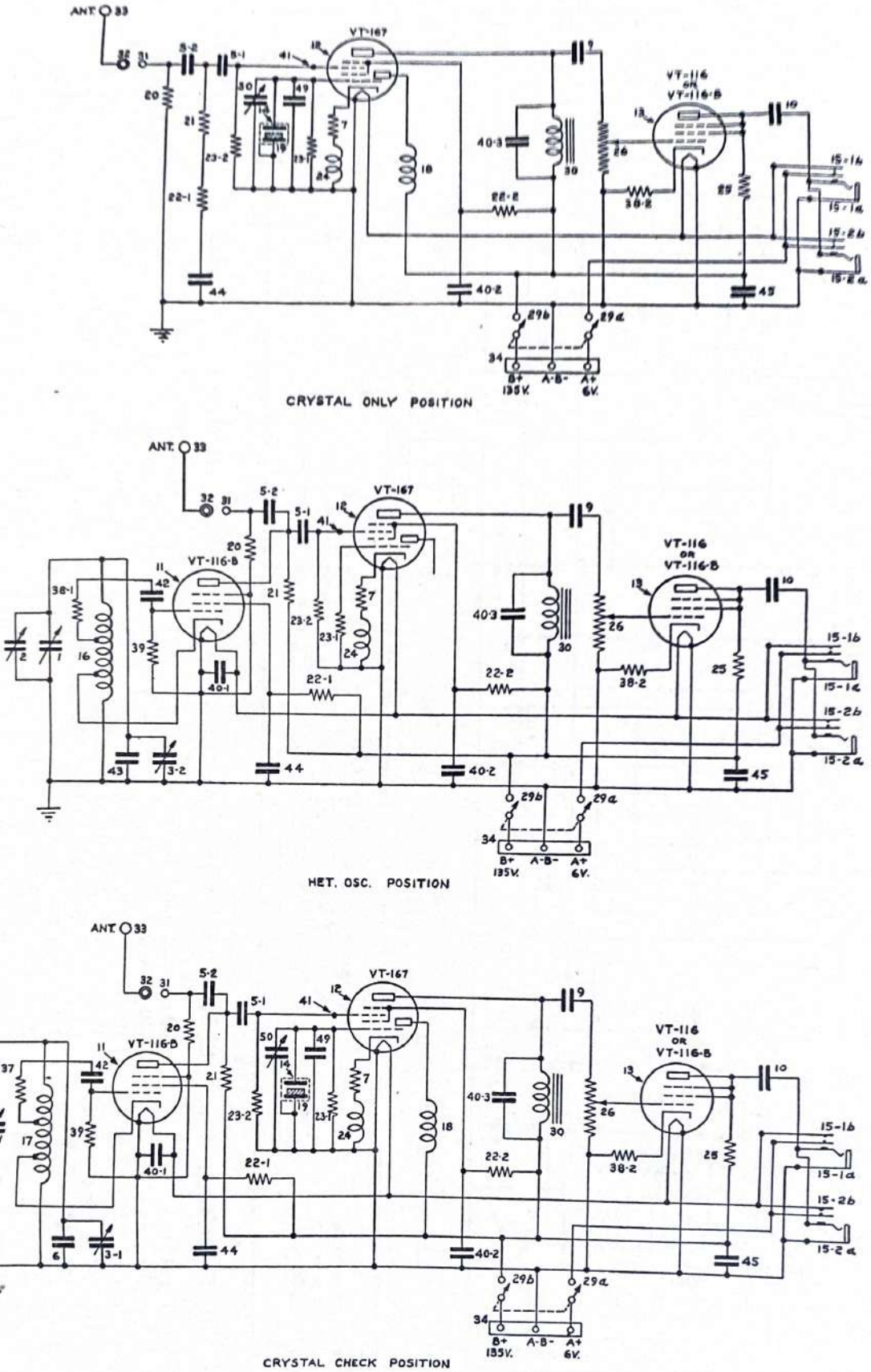
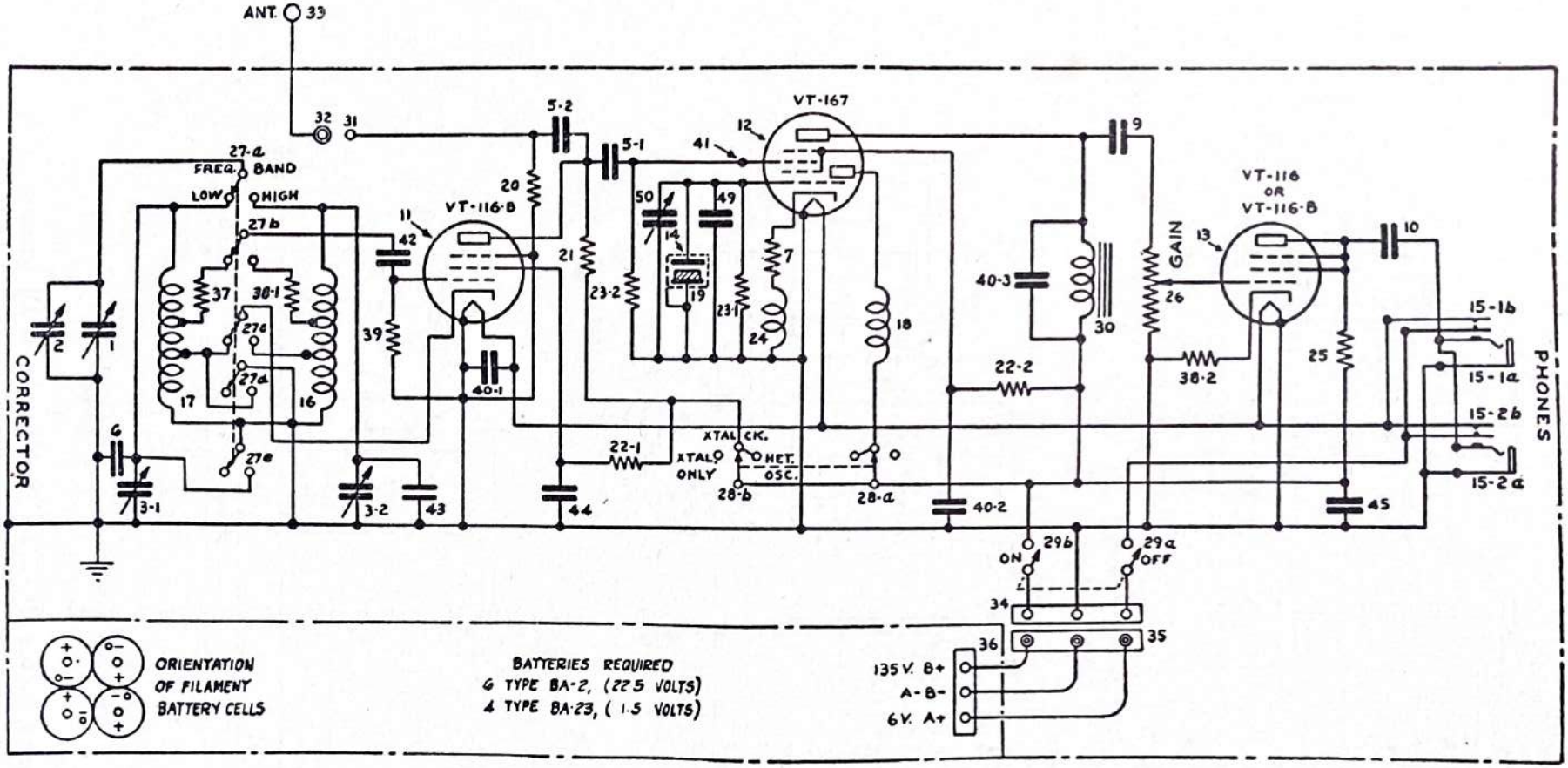


FIGURE 12—Frequency Meter BC-221-( ), Functional Diagrams



REF.	DESCRIPTION
1	160 $\mu\mu f$
2	3 $\mu\mu f$
3-1	10 $\mu\mu f$
3-2	10 $\mu\mu f$
5-1	10 $\mu\mu f$
5-2	10 $\mu\mu f$
6	7 $\mu\mu f$
7	180 Ohms
9	.02 μf
10	0.5 μf
15-1a	Phone Jack
15-1b	Fil. Switch

REF.	DESCRIPTION
15-2a	Phone Jack
15-2b	Fil. Switch
16	34.0 Micro-H
17	9.05 Milli-H
18	735 Micro-H
19	Crystal
20	5,000 Ohm
21	50,000 Ohm
22-1	8,750 Ohm
22-2	8,750 Ohm
23-1	1 Megohm
23-2	1 Megohm

REF.	DESCRIPTION
24	15.8 Micro-H
25	15,000 Ohm
26	0.5 Megohm
27a thru 27e	Switch
28a, 28b	Switch
29a	Switch
29b	Switch
30	450 Henries
37	4,500 Ohm

REF.	DESCRIPTION
38-1	350 Ohm
38-2	350 Ohm
39	150,000 Ohm
40-1	.001 μf
40-2	.001 μf
40-3	.001 μf
42	100 $\mu\mu f$
43	10 $\mu\mu f$
44	0.1 μf
45	0.7 μf
49	6.0 $\mu\mu f$
50	14.5 $\mu\mu f$

FIGURE 13—Frequency Meter BC-221-( ), Schematic Diagram

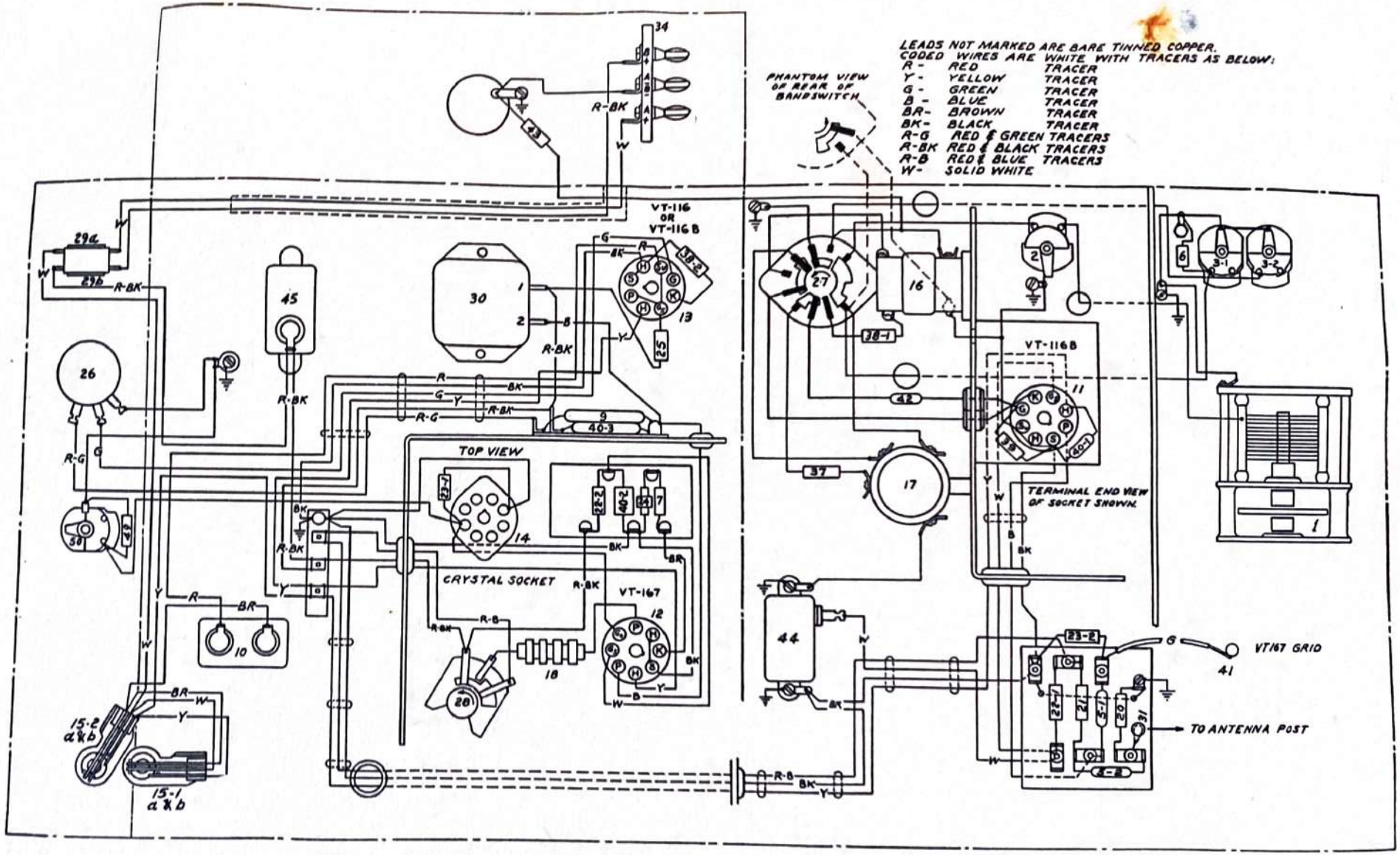

LEADS NOT MARKED ARE BARE TINNED COPPER.
CODED WIRES ARE WHITE WITH TRACERS AS BELOW:
R - RED TRACER
Y - YELLOW TRACER
G - GREEN TRACER
B - BLUE TRACER
BR - BROWN TRACER
BK - BLACK TRACER
R-G RED & GREEN TRACERS
R-BK RED & BLACK TRACERS
R-B RED & BLUE TRACERS
W - SOLID WHITE
PHANTOM VIEW OF REAR OF BANDSWITCH
VT-116 OR VT-116 B
VT-116B
TOP VIEW
TERMINAL END VIEW OF SOCKET SHOWN
CRYSTAL SOCKET
VT-167
VT167 GRID
TO ANTENNA POST

FIGURE 14—Frequency Meter BC-221-( ), Chassis Wiring Diagram

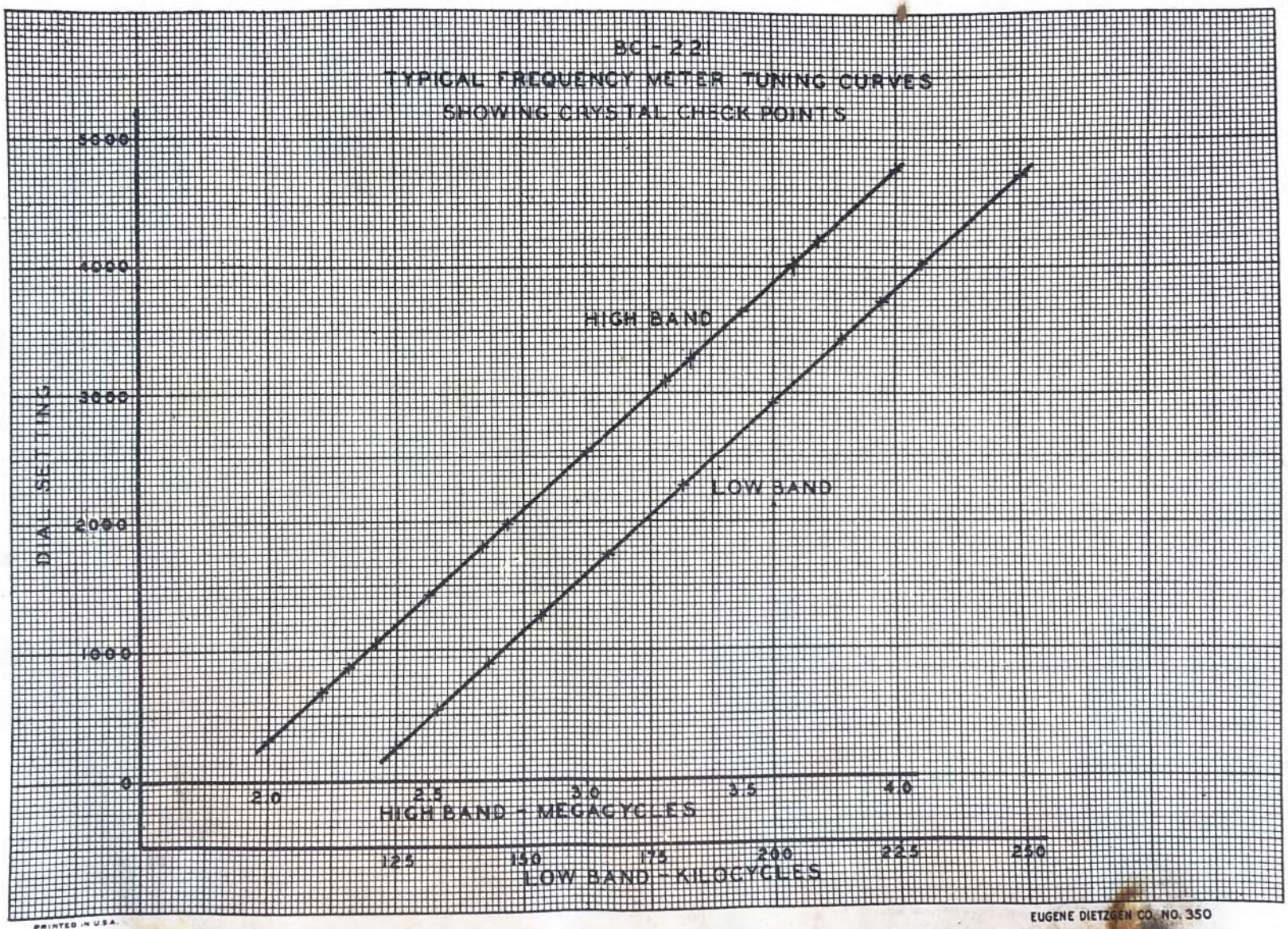


FIGURE 15—Frequency Meter BC-221-( ), Typical Het. Osc. Tuning Curves